LABORATORY GUIDE

ENTOMOLOGY

OESTLUND

A

LABORATORY GUIDE

IN

ENTOMOLOGY

For use as an Introduction to the Study of Entomology, and as Introductory to a Course in General Zoology.

BY

OSCAR W. OESTLUND

H. W. WILSON
UNIVERSITY BOOK STORE
MINNEAPOLIS
1900
S

Price 50c. post-paid.

CONTENTS.

		Page.
Introductory,		5
I.	Structure of the Insect Body in General	9
II.	Larval Forms of Insects,	12
III.	Metamorphosis of Insects,	15
IV.	Wings of Insects,	21
V.	Mouth-parts of Insects,	25
VI.	Internal Anatomy of Insects,	31
VII.	Classification of Insects,	37
VIII.	Directions for Making a Collection,	48

INTRODUCTORY.

This brief Laboratory Guide to the study of insects has been prepared for use in the writer's own classes as an introduction to a more advanced course in entomology, and also for use as introductory to a general course in zoölogy. Its presentation to the public is with the hope that teachers of natural history, especially those of our own State, may in it find something to commend itself to them; and that much of this work, which at present must be done by the University, may in the near future be done, in part at least, by our preparatory schools. The importance of the study of zoölogy in High Schools, Academies, and Colleges is gradually being recognized; but in too many cases it still stands back in comparison with other branches of natural history, as that of botany. One of several reasons for this is no doubt to be found in the difficulty of the subject as usually taught. The study of zoölogy from the biological or laboratory standpoint, the only standpoint from which the subject can be studied as too often understood by our teachers, requires apparatus and skill that few possess. The study of protoplasm, the cell, and protozoans, though this may be the logical starting point for the study of zoölogy, nevertheless presents so many difficulties that it may well be questioned if it be advisable to confound the beginner with them, and more often probably fostering a dislike than a love for the subject. To begin, on the other hand, with one of the higher types, as a vertebrate, also presents a number of objectionable points, which, unless in the hands of a most competent teacher, will not give the desired results in a large and mixed class of young minds.

Insects no doubt present the most favorable group that can be chosen for beginning the study of general zoölogy. Few of the objections in beginning with the protozoans or in dissecting the frog, or some other vertebrate will be found here. Insects are abundant everywhere, and so varied in their mode of life

that the interest of the scholar or the student is at once drawn to the subject. In dissecting a larva or an insect there is little that is repulsive even to the young mind; and the fundamental laws of zoölogy may as well be taught from a study of insects as from that of a vertebrate.

It is a hopeful sign that we are now beginning to recognize that the laboratory alone is not sufficient for a correct understanding of zoölogy. The laboratory is a most important factor—a necessity; but if the laboratory be not supplemented by a study of the animal as a living object, the knowledge is prone to become one-sided and often misleading. Systematic zoölogy, and I take it in its broadest sense, and a study of the living object, should go hand in hand with that of the laboratory. The following pages have been prepared with these objects in view. The forming of a collection by the student will at once put him in direct contact with zoölogy as a study of living objects, especially so if under the direct guidance of the teacher; otherwise the chapters on classification and directions for collecting should in part supply this. The laboratory work aims to supply the special knowledge of anatomy necessary for the correct study of the living animal; to teach correct methods of the laboratory from the very beginning; and to lead to a better comprehension of the more important fundamental laws of zoology, which, of course, must be supplied by the teacher or text-book in class-room work.

A more or less radical departure from what is usually found in text-books on the subject, will be found in not a few places. Some explanations may therefore not be out of place, and I regret only that I cannot in this connection also give a full discussion of some of them. Insects pass through three distinct periods or stages and not four as usually taught; the so-called pupa stage is the exception and not the rule. A factor of much deeper phylogenetic significance than what has hitherto been recognized is undoubtedly to be found in the modification of the front pair of wings in some orders of insects, making the two pairs of wings dissimilar, and the retention of the hind pair of first importance in flight; while in others the two pairs of wings remain similar and the front pair becomes of first importance in flight. The application of this will be seen in the chapter on

classification. The chapter on the metamorphosis of insects has been recast and altered from what is usually given on the subject; with what success, the future will have to determine. The insufficiency of the present application of the great facts of metamorphosis in explaining the phylogeny of insects is too well known by all students of the subject.

The jointed beak of the Rhynchota has little in common with the so called sucking mouth-parts of other orders, when examined from a phylogenetic standpoint, and will undoubtedly generally become recognized as forming a separate series as here proposed, and as the results of several recent investigations on the group would seem to point out. The interpretation of the so called lacinia has too long been a stumbling block to the correct understanding of the mouth-parts of insects in correlation with those of other Arthropoda; the present interpretation will obviate this.

The recognition of only eight orders in place of sixteen or more, generally given in our more recent text-books, may by some be considered as a step backward. Brauer's system of classification is undoubtedly in the right direction, and our text-books may be commended for taking this forward step; but that as yet there are so many points unsettled in connection with this scheme, and that a logical application of Brauer's own interpretation would probably give us at least 25 orders in place of the 17, I deem it the best, from a practical standpoint, to retain the so called seven orders of Linnæus as a basis in an introduction to a more advanced study of the modern classification of Brauer and others. These seven or eight orders have long been tried and may be said to form well defined and natural orders or groups to which even the most modern interpretation of insect phylogeny may be applied. The student that has mastered the phylogeny of the eight orders here given will be better prepared, I think, to take up the more advanced schemes and not too easily led astray.

With full recognition of the fragmentary condition of the work in its present form, the object not being to give a full account of the elements of entomology, but rather to point out methods and to call attention to some of the more fundamental facts leading to a better understanding of the classification of

insects; the author nevertheless hopes that he has succeeded, to some extent, in presenting the subject in simplicity and clearness for the student as well as the teacher; and that some of the suggestions may even be of aid to fellow workers in insect phylogeny.

Very few illustrations are introduced for the reason that the student is expected to prepare his own to accompany the work. The few found in the chapter on classification were kindly loaned by Dr. Otto Lugger, of the Agricultural College and Experimental Station, St. Anthony Park.

O. W. O.

University of Minnesota,
Sept. 1, 1900.

CHAPTER I.

STRUCTURE OF THE INSECT BODY IN GENERAL.

Insects have a firm outer covering known as the *exoskeleton*, which also serves as a protection to the soft internal organs and for the attachment of muscles. The exoskeleton is principally composed of a substance known as *chitine*. This skeleton is not continuous over the whole body, but is separated into a certain number of rings or *segments* that follow one another in the long axis of the body; hence the body of insects is said to be segmented. This segmentation also extends to some of the internal organs. The chitinous ring around each segment is not continuous around the body, but is deposited in plates or *sclerites*, of which we can always distinguish two; a dorsal, the *tergum*, and a ventral, the *sternum*. Between the tergum and the sternum there may be present, on either side, one or more smaller sclerites known as *pleura* (sing. pleuron). The segments are not all alike but differ more or less in different parts of the body, so that they may be grouped into three regions, each of which has peculiarities of its own. These three regions are generally known as the *head*, *thorax*, and *abdomen*. The head is theoretically composed of six segments, but these can no longer be distinguished in insects except from a study of their embryonic development. It is the region of the principle sense organs, and also carries the mouth-parts. To the thorax belong the three segments that follow the head; these can readily be distinguished, though they may also show more or less fusion. The first segment is known as the *prothorax*, the two following respectively as the *mesothorax* and the *metathorax*. The thorax is preëminently the region of locomotion (not a thoracic as usually understood by this term), as it carries the principal organs of locomotion, the legs, and in the adult stage the wings. The abdomen has from seven to eleven segments, none of which carries organs of locomotion.

Insects are further characterized by having a pair of jointed appendages to each segment. But these are not all present except in early stages of the embryo. In the larva and the adult insect, four pairs are usually present on the head region; a pair of *antennae*, and three pairs of *mouth-parts*. The thorax carries a pair of legs to each segment. The abdomen, as stated above, carries no appendages, except in some cases there may be present on some of the terminal segments a pair of antennæ-like organs, the *cerci* or setæ, or still more modified as accessory reproductive organs, as stings, breathing pores, etc. The larva may sometimes be provided with legs on the abdomen; these are not true appendages but of secondary origin known as *pro-legs* (or false legs).

If one of the walking-legs be examined it will be found to have the following joints, beginning with the proximal one: *coxa, trochanter* (usually very small), *femur, tibia,* and *tarsus.* The tarsus is composed of one to five smaller joints, which are considered as forming a secondary jointing. A pair of *claws* is usually present on the distal end of the tarsus.

LABORATORY DIRECTIONS TO CHAPTER I.

Plate I. **Fig. 1.** **x3.**

Campodiform larva of Dytiscus (or of some other insect).

In describing or making a drawing of an animal, it should always be considered in its natural position, with the head forward or away from you and the ventral side down. The body of an insect may be considered to form a cylinder, the head being the anterior and the opposite the posterior ends; with the ventral side down and the dorsal side up, the right and left sides of the observer become the right and left of the object. Passing an imaginary line from the anterior end to the posterior through the middle, it becomes the mid-axis or long axis of the body; if similar lines are drawn at right angles to the long axis passing from the dorsal to the ventral, or from the right to the left, these will then form the dorso-ventral and the right and left or transverse axes of the body. These are also spoken of

as the short axes of the body. A plane passing through the dorso-ventral axis in line with the long axis will divide the body into two equal parts, a right and a left; this expresses the bilateral symmetry of the insect body. The appendages of insects are always spoken of in reference to the long axis of the body; the point of attachment being the proximal and the free end the distal parts of such an appendage. The proximal is also sometimes spoken of as the base and the distal as the apex.

The number of the plate, or sheet of drawing paper, should be indicated in the upper right hand corner. The number of the figure (fig. 1) should be put below the drawing when completed, with the scale to which the drawing has been made. The figure $\times 3$ indicates the scale; in this case three times the actual size of the body. First lay off on the paper the long axis of the body three times its actual length, and in the same way lay off the short axis of the body for the different regions, and outline your drawing. Use a hard pencil and at first put in your lines faintly; afterwards they may be drawn more fully or put in ink if so desired.

Make a drawing of the dorsal view and name the following parts: *A*, anterior; *P*, posterior; *R*, right; *L*, left; *h*, head; *t*, thorax; *ab*, abdomen; *pr*, prothorax; *me*, mesothorax; *mt*, metathorax; number the segments of the abdomen beginning with the one next to the thorax; *an*, antenna; *o*, ocellus; *e*, eye; *bt*, breathing-tube..

These letters should be put on your drawing; carefully indicating just what part the letter refers to by drawing dotted lines when necessary; write out the explanations or index to the letters below or alongside of the drawing, or they may be written on a separate page to be headed explanations to plate I. fig. 1.

Plate I. **Fig. 2.** **x5.**

Left leg of Dytiscus.

Make a drawing to the scale indicated and name the following parts: *c*, coxa; *tr*, trochanter; *f*, femur; *ti*, tibia; *ta*, tarsus; number the joints of the tarsus from the proximal end; *cl*, claw.

When a plate is completed, the student should put his name or initials in the lower left-hand corner.

CHAPTER II.

LARVAL FORMS OF INSECTS.

There are three distinct stages in the life history of an insect: the *egg*, the *larva*, and the adult or *imago*. The egg-stage constitutes the period of embryonic development. The larval stage the period of growth, and also that of change, or post-embryonic development. The imago or adult stage is the period of reproduction and distribution of the species. The variation in form of the insect larvæ is very great; it may, nevertheless, be reduced to three types. These are:

1. **Campodiform.** In this type the antero-posterior axis of the body is very long in comparison with the dorso-ventral. The body is more or less distinctly flattened, with a well marked dorsal and ventral aspect. The three regions of the body are distinctly marked. The head is well marked and usually horizontal in position with the long axis of the body. The thorax is provided with well developed legs, adapting the larva to an active life. A pair of cerci are usually present on the abdomen. This type has been drawn as fig. 1.

2. **Eruciform.** In this type the long axis of the body is somewhat shorter and the dorso-ventral somewhat longer in comparison with the same in the campodiform type. The body is cylindrical in outline, making the dorso-ventral axis equal or nearly so to the right and left. The head is more or less vertical in position, and smaller in proportion to the bulk of the body. The three regions of the body are less distinctly marked, especially that of the thorax. The legs of the thorax are usually small, and often supplemented by prolegs on the abdomen. Abdomen usually without cerci. Larva of this type are generally known as *caterpillars*.

3. **Apodiform.** In this type the long axis is distinctly shortened in comparison with the proportions of the preceding types, and sometimes not much longer than the dorso-ventral.

The body is short and cylindrical, with no well marked dorsal and ventral aspect. The three regions of the body are not easily distinguished, the segments being nearly all alike. There are no legs to the thorax. The head is small and ill defined, often more or less retracted. The mouth-parts are sometimes reduced to a pair of hooks. Abdomen without cerci. The larvæ of this type are generally known as *maggots*.

The campodiform type is considered as the primitive form of the insect larva. It is a generalized type from which the other two can be derived. The larva differs less from the imago than in the case of either of the other types; and this form may therefore be taken as typical of the insect body in general. The larvæ are all active and usually predacious, running about in search of food. The eruciform larva is considered as a modification of the campodiform type. This modification is undoubtedly due to a greater abundance of food and more favorable conditions under which it can be secured. The eruciform larvæ are, as a rule, plant feeders and need not travel far in search of food. The apodiform larva is but an extreme modification of the eruciform. Its food is in abundance and more accessable than even that of the caterpillar. Its food is usually in manure-heaps, carcasses, decaying animal and vegetable matter, or it develops parasitically within plants and animals; and in some cases the larvæ are fed by the parent insect.

LABORATORY DIRECTIONS TO CHAPTER II.

Plate II. **Fig. 3.** **x4.**

Eruciform Larva of a Butterfly (the Caterpillar).

Make a drawing of a lateral view from the left side, and name the following parts: *A*, anterior; *P*, posterior; *D*, dorsal; *V*, ventral; *h*, head; *t*, thorax; *ab*, abdomen; number the segments of the abdomen; *pl*, prolegs; *s*, stigmata; *prl*, prothoracic legs; *msl*, mesothoracic legs; *mtl*, metathoracic legs.

Note that this specimen illustrates in comparison with fig. 1, a vertical position of the head; a less differentiated thorax;

reduced jointed legs; accessory legs to the abdomen; a cylindrical body.

Plate II. Fig. 4. x6.

Apodiform Larva of a Fly (the Maggot).

Make a drawing of a lateral view from the right side and name the following parts: *A*, anterior; *P*, posterior; *h*, head; *t*, thorax; *ab*, abdomen; number the segments of the abdomen; *mh*, mouth-hooks; *s*, stigmata; *ps*, posterior pair of stigmata.

Note that this figure in comparison with the preceding, shows a very much reduced head; practically no division into regions; absence of all appendages on thorax and abdomen; mouth-parts reduced to a pair of hooks; the body much reduced in size.

CHAPTER III.

METAMORPHOSIS OF INSECTS.

In examining the imago of the larvæ treated of in the preceding chapters, a marked difference will be found to exist between the two. The imago is provided with one or two pairs of wings; the mouth-parts may be of a very different type; the exoskeleton is more highly developed; and in a number of other points, both of external as well as of internal anatomy, a decided difference may be present. Wings are never present in the larvæ of insects; but sooner or later there appear two pairs of dorso-lateral outgrowths on the thorax which are known as *wing-pads*. As larval organs, in all probability, they had some other function than that of locomotion; there are reasons for believing that this was a respiratory function. It is these larval organs that become changed into organs of locomotion, or *wings*, in the adult. Such a change in function of a larval organ, with the corresponding change in structure, constitutes a *metamorphosis*, or post-embryonic development so characteristic of insects as a class. Other organs besides the wing-pads may also be subject to a change in the larva before reaching the adult stage, which must also be considered as a metamorphosis.

There is also another phenomenon in the life-history of insects that is intimately connected with metamorphosis, which may be considered in this connection. The larvæ of insects are well known to refuse all food at certain intervals of their development, and become more or less inactive. This is preparatory to the casting off of the outer body-covering or the skin, with the exoskeleton. Such a casting off is known as a *moult* or *ecdysis*. In number the moults of insects are quite variable; while some may have as many as twenty or more, the largest number of insects have but five or six or less. Moulting is generally considered to be the result of the rapid growth of the insect larva together with the presence of the exoskeleton, which

would not allow of sufficient expansion to accommodate the rapid increase of the body. In all probability it also has a more primitive and deeper significance. It has been well suggested that this may have been an excretory function: that the secretion forming the exoskeleton originally was an excretion, and that a too great accumulation of this substance, resulting from the active life of the insect, was gotten rid of from time to time by means of an ecdysis. In primitive insects moulting no doubt extended through life, including the adult stage; in all modern insects, with one exception, moulting has become lost in the imago. This loss may be accounted for by the presence of wings. In the May-flies (Ephemeridæ) an ecdysis belonging to the imago is still present. The significance of this ecdysis should not be overlooked.

The various orders of insects differ more or less in the mode in which the metamorphosis is accomplished and also in its degree or amount. Metamorphoses may be arranged under the following types.

1. **Gradual Metamorphosis.** In this type the change that constitutes the metamorphosis is not separated from that of growth, but takes place at the same time in the larva. The Locust may serve as an example. The larva is of the campodiform type with well developed legs. After a certain number of moults the wing-pads will appear as external larval organs; these will show a gradual increase after each succeeding moult until the larval period is completed, when the last moult will transform the larva into the imago with well developed organs of flight—the wings. This type of metamorphosis is characteristic of the Orthoptera, the Rhynchota, and of the Neuroptera in part.

2. **Interrupted Metamorphosis.** In this type the change has become separated from that of growth. The larval period, or period of growth, has become shortened or interrupted; and the change that takes place is concentrated in the last part of the larval period. This may be considered as forming a distinct period in these insects, and is known as the *pupa* stage. The beetle (Dytiscus) may be taken as an example of this type. The campodiform larva, as in the preceding example, continues to grow and moult, but the wing-pads will not appear as external larval organs until after the last but one moult. Just previous

to this moult the larva is already fullgrown and will not take any more food, but conceals itself in the ground or in some secure place and becomes inactive. After moulting has taken place it will appear as a very different creature, no longer capable of running about or of taking food, and the wing-pads will suddenly appear as prominent external organs. It thus becomes a pupa, that part of the larval period in which all or most of the change takes place. The imago will appear with well developed wings after the last moult. This type of metamorphosis is characteristic of the Coleoptera, and of the Neuroptera in part.

3. **Trophic Metamorphosis.** This type does not differ from the preceding as far as the metamorphosis of the wing-pads into organs of flight is concerned, and is, therefore, usually not considered as a distinct type, though there are good reasons for so doing. In addition to the metamorphosis of the wing-pads there also takes place, at the same time, a complete metamorphosis of the mouth-parts. The mouth-parts of the larva are adapted for biting (*mandibulate*), while those of the imago are adapted for sucking (*suctorial*). The butterfly may serve as an example of this type. The caterpillar has the mouth-parts adapted for biting and crushing as it feeds upon tissues of plants. After the last but one moult it becomes a pupa, similar to that of the beetle, but usually known as a *chrysalis* for the butterflies. When the imago appears after the last moult, the mouth-parts will be found to form a long tongue-like organ adapted for sucking the nectar of flowers and other fluids. Trophic metamorphosis is characteristic of the Lepidoptera, Diptera, and the higher Hymenoptera.

4. **Hypermetamorphosis.** This type is characteristic of a small number of insects belonging to various orders but mostly beetles. In addition to the typical metamorphosis (*interrupted* or *trophic*) characteristic of the order, the larva is subjected to a distinct metamorphosis confined to the early larval period. It is in fact a double metamorphosis; one in early larval life, and one in late larval life leading to the imago. As an example of this type may be taken one of the oil-beetles (Sitaris). The larva on hatching is distinctly campodiform, and provided with legs adapted for active life. It is carnivorous in habit, feeding on eggs of certain bees. After the first moult the larva becomes

apodiform, the legs being rudimentary or lost, and no longer adapted for active life. The mouth-parts also become more or less reduced or changed, differing much from the biting (mandibulate) mouth-parts just preceding. They are now adapted for taking liquid food (suctorial), as the larva no longer feeds upon the eggs of bees, but upon the honey in the cell put there by the bee as food for its own larva. After the customary number of moults the larva will become a pupa, in which stage the characteristic metamorphosis of the wing-pads into wings will take place. There is a very great variation in the mode of acquiring the first larval metamorphosis.

5. **Suppressed Metamorphosis.** In the preceding types we have seen an ever increasing amount and complexity in the metamorphosis. On the other hand we find in various orders of insects examples in which the metamorphosis has become more or less suppressed, and in some cases almost lost, so that the imago differs but slightly from the larva. Suppressed metamorphosis is not characteristic of any order as a whole, but appears in smaller groups in the various orders. The causes leading to a suppression of metamorphosis are various, but in many cases it is undoubtedly due to the parasitic or semiparasitic habit of the insect. As example may be given the body-lice (Pediculina), bird-lice (Mallophaga), bed-bug, etc.

The term *Ametabola*, or without metamorphosis, is applied to a small group of insects (Thysanura) which are supposed to be directly descended from the original stock of insects before metamorphosis had become characteristic of the class.

Metamorphosis is probably one of the most interesting phenomena in the varied life-history of insects. The student should endeavor to grasp clearly the relationship of the different types, as this will go far to clear up the phylogeny or classification of insects to be considered further on. Gradual metamorphosis, where the change takes place alongside of that of growth, is undoubtedly the primitive type of metamorphosis of insects. Interrupted metamorphosis can readily be derived from the gradual. In it a complete separation of a period of change from that of growth has taken place, and the phenomenon of a pupa stage first appears. In trophic metamorphosis the change has come to include that of the mouth-parts. In hypermetamorphosis a dis-

tinct metamorphosis takes place in early larval life in addition to the one leading to the imago. A greater or less suppression of metamorphosis may take place in the various orders.

In insects with gradual metamorphosis, the larval period is normal and there is no pupa stage. It has become customary of late to designate these as the nymph, and to restrict the term larva to the early larval period of those insects that develop the pupal stage in late larval life. Such a restriction of the term larva is not logically correct. The term nymph was originally applied to the larva of insects with a gradual metamorphosis in which the wing-pads had become apparent as external larval organs, correlating it with the so called pupa of other insects; but as the limit of time when the wing-pads first appear as external organs is variable and indefinite, it was no doubt this that led to the gradual extension of the term nymph to the whole larval period. The term may still be applied to the May-flies (Ephemeridæ) to distinguish the early period of the adult preceding the last moult that takes place in the imago.

LABORATORY DIRECTIONS TO CHAPTER III.

Plate III. **Fig. 5.** **x3.**

Larva of the Locust with wing-pads.

Cut off the legs on the left side close to the body; sketch this side and name the following parts: *h*, head; *t*, thorax; *ab*, abdomen; number the segments of the abdomen both dorsal and ventral; *an*, antenna; *e*, eye; *o*, ocellus; *pr*, prothorax; *wp'* wing-pads of mesothorax; *wp''*, wing-pads of metathorax.

Plate III. **Fig. 6.** **x5.**

Pupa of a Beetle.

Sketch the ventral side and name the following parts: *h*, head; *t*, thorax; *ab*, abdomen; *wp*, wing-pads; *l*, legs; *an*, antenna.

Plate III. **Fig. 7.** **x4.**

Pupa of a Butterfly.

Sketch the right side and name the following parts: *A*, anterior; *P*, posterior; *h*, head; *t*, thorax; *ab*, abdomen; *an*, antenna; *wp*, wing-pads; *st*, stigma.

CHAPTER IV.

WINGS OF INSECTS.

We have already called attention to the fact that the wings of insects are larval organs that become changed into organs of flight in the imago. There are never more than two pairs present: the front pair on the mesothorax, and the hind pair on the metathorax. When only one pair is present one has become changed or lost. In structure they are pouch-like out-growths that become much flattened, forming two *laminae* or plates, an upper and a lower, closely united so as to appear as a single lamina. The proximal part of the wing, or the point of attachment, is known as the *base*; the distal as the *apex*; the anterior side of the wing is the *anterior* or *costal margin.* and the one opposite the *posterior* or *anal margin.* In some insects, where the wings are very broad and triangular in outline, as in the Lepidoptera, the hind margin may be separated into two: the proximal, or *anal margin*, and the distal, or *apical margin.* The two laminæ of a wing are in a majority of insects thin and membranous, and united together into a single membrane by a number of chitinous ridges that run from the base towards the apex. The hollows between the ridges at first contain trachea with blood circulating about them, which later on become very much reduced or disappear. These ridges are therefore known as *veins*, and are of very great importance for the classification of insects. The principal longitudinal veins running from the base to the apex are six in number and taken from the anterior margin are named as follows: C, *costa*; Sc *subcosta*; R, *radius*; M, *media*; Cu, *cubitus*; An, *anal.* Of the last there may be more than one. There is a very great variation in the position of these veins, and they can not be found in their simple or primitive position except in a very few insects, or at the time of the metamorphosis of the wing-pads into wings. The subject becomes even more complicated by the presence of a number of

additional or secondary veins in most insects; or, on the other hand, by two or more of the longitudinal veins becoming fused into one or completely lost. The subject of the venation of the insect wing, though of the greatest interest and importance, presents, for the present at least, too many difficulties to be given in an elementary course. The longitudinal veins may be connected by smaller veins known as *cross-veins*. The space inclosed by two longitudinal veins connected by one or more cross-veins is known as a *cell*. In many insects the anterior margin has a cell or space thickened, and usually of a different color, known as the *pterostigma*.

Wings of insects are typically membranous, but in some, as in the Lepidoptera, they may be covered with hairs or scales so as to obscure the membranous character. And in others the front pair may become more or less thickened and adapted rather for protection than as organs of flight. In the Orthoptera, where the front pair is more or less parchment-like, they are known as *tegmina*; in the Coleoptera they become very thick and shield-like and are known as *elytra*; while in the Heteroptera the basal part is thickened but the tip remains membranous, and the wings are then known as *hemelytra*.

In primitive insects the two pairs of wings were similar in character and equal in size, but this condition is now found in but few insects; the dragon-flies among the Neuroptera probably coming nearest. In a majority of insects a modification of this primitive condition is seen to take place in two directions, giving two distinct types of wings.

1. **Plicata Type.** In this type the two pairs of wings are dissimilar. The front pair is reduced in size and modified for protection; the hind pair is membranous and constitutes the principal means of flight. When at rest the hind pair is folded in various ways to fit under the front pair. This type of wings is characteristic of the Orthoptera, Coleoptera, and Heteroptera. Some of the Neuroptera and Homoptera may show an approach to this type in the modification of the front pair of wings. One of the causes leading to a modification of the front pair of wings according to this type, is no doubt to be found in the terrestrial habit of these insects; living on herbage, usually close to the ground, they make use of the legs as the ordinary mode of

locomotion even in the imago stage, and the wings become secondary or exceptional organs of locomtion closely correlated with the reproduction and distribution of the species, which is the primitive function of the wings as organs of locomotion.

2. **Aplicata Type.** In this type the two pairs of wings are similar, but the hind pair usually shows a reduction in size, or may be absent. The front pair becomes the principal pair for use in flight. Hind wings are not folded when at rest or only in part (anal area). This type is characteristic of the Homoptera, Neuroptera, Hymenoptera, Lepidoptera, and Diptera. In comparison with the foregoing type these insects are preëminently aerial insects in the adult stage, making use of the wings as their principal mode of locomotion; the legs being of secondary importance. In the imago stage they live more exposed, being much upon the wings.

LABORATORY DIRECTIONS TO CHAPTER IV.

Plate IV. **Fig. 8.** **x2.**

Right front wing of a Locust. (Tegmina).

Sketch and name the following parts: *b*, base; *ap*, apex; *cm*, costal margin; *an*, anal margin.

Plate IV. **Fig. 9.** **x2.**

Right hind wing of a Locust.

Sketch and name the following parts: *cm*, costal margin; *apm*, apical margin; *an*, anal margin; *lv*, longitudinal vein; *cv*, cross-vein; *cl*, cell.

Plate V. **Fig. 10.** **x3.**

Right front wing of a Butterfly.

Sketch and name the following parts: *Sc*, subcosta; *R*, radius; *Cu*, cubitus; *A*, anal; (the costa is wanting, and the media is absent on the basal part of the wing); show the distribution of the color spots.

Plate V. **Fig. 11.** **x3.**

Right hind wing of a Butterfly.

Sketch and name the same parts as for fig. 10.

Plate V. **Fig. 12.** **1 inch.**

Scales from the wings of a Butterfly.

Scrape off some of the scales and mount on a slide and examine under the microscope. Make your sketch large enough so as to measure at least one inch in length.

CHAPTER V.

MOUTH-PARTS OF INSECTS.

By the mouth-parts or trophi of insects we understand those paired appendages and other parts of the body that serve as accessory organs of the mouth. Of the paired organs there are three: the first pair of jaws or *mandibles*; the second pair of jaws or *maxillae*; and the third pair of jaws, or second pair of maxillæ, which in all insects are fused together into a single organ—the *labium* or under lip. Of the unpaired parts there may be present: the *labrum* or upper lip, which is considered as one of the anterior sclerites of the head; the *epipharynx* or upper tongue, a tongue-like prolongation from the upper side of the mouth; and the *hypopharynx* or lower tongue, a similar prolongation from the lower surface of the mouth.

The mouth-parts of insects are considered as primitive (mandibulate) in which the paired appendages are present as jaws adapted for biting or for taking solid food; or, on the other hand, as modified where one or more of the jaws are adapted for piercing and sucking or for taking liquid food (suctorial). Of the modified mouth-parts we have several distinct types. We may therefore consider the mouth-parts under the following heads.

1. **Mandibulate Type.** In this type the first pair of jaws or mandibles is present as a pair of stout unjointed organs, provided on the inner side with protuberances or spines, adapted for grasping or tearing the food. The second pair of jaws or maxillæ are more complex and composed of several distinct parts, viz.: A basal part composed of two joints known as the *cardo* and *stipes;* attached to the distal end of this part there is on the outer side a series of small joints, usually five in number and similar to those of the antenna, known as the *palpus* or feeler; along the side of the palpus there is another, one or two jointed, finger-like organ known as the *galea;* and on the inner side of this a third one-jointed part, similar to the mandibles,

known as the *lacinia*. In the third pair of jaws, or second pair of maxillæ, the two basal parts have become fused and are no longer known as cardo and stipes but as the *submentum* and *mentum;* attached to the distal end of these fused parts the corresponding parts of the first maxillæ (palpus, galea, and lacinia) are usually to be found, although they may be much reduced in size or fused. When the second pair of maxillæ is considered as a fused and single organ it is known as the *labium* or underlip. The labrum or upper lip partakes more of the character of a sclerite than of an organ of the mouth. The epipharynx and hypopharynx show but slight development in this type. Mandibulate mouth-parts are characteristic of the Orthoptera, Coleoptera, Neuroptera, some Hymenoptera, and the larva of Lepidoptera.

2. **Hymenoptera Type.** Many of the Hymenoptera have mandibulate mouth-parts and fall under the preceding type, but the bees and allied forms have them changed into organs for sucking according to a type peculiar to this order. The mandibles are present but usually with no prominent protuberances or spines on the inner side. The maxillæ are greatly modified; the cardo and stipes are long and slender joints; the palpus is usually much reduced; the galea is wanting, but the lacinia forms a large blade-like organ, probably adapted for cutting and piercing and also serving as a sheath for the labium. The labium shows a still greater modification: the palps are present and prominent, the basal joints being much enlarged and lengthened; the galea is rudimentary, but the two lacinæ are developed into a long tongue-like organ adapted for feeding on the pollen and nectar of flowers. This type is characteristic of the Hymenoptera.

3. **Lepidoptera Type.** The larva of Lepidoptera has mouth-parts of the primitive or mandibulate type, as already stated, but in the imago they become changed into highly specialized organs adapted for taking liquid food. The mandibles are completely lost or found in a very rudimentary condition. The maxillæ show a high degree of specialization; the palps are rudimentary, the galea is wanting, but the laciniæ are modified into a tongue-like organ, similar to the modified lacinia of the labium of the Hymenoptera, very long and flexible and capable of be-

ing coiled up like a watch-spring when at rest. The labium shows great reduction in parts; the palps are well developed, but the submentum and mentum are fused into a single transverse piece, and the galea and lacinia are wanting. This type is peculiar to the Lepidoptera in the imago stage.

4. **Diptera Type.** In the Diptera we find the most highly modified mouth-parts of all insects, but which are subject to considerable variation. But these may all be referred to the type probably best seen in the mosquito. Here the mouth-parts are not only modified for sucking, as in the two preceding types, but also for piercing. The mandibles and the maxillæ are therefore here changed into four slender needle-like organs known as stylets, and in addition to this the labrum and the epipharynx are similarly modified. These six stylets form a sort of capillary tube by means of which the fluids are sucked into the mouth. The labium forms a sheath or case for the stylets, and takes no active part in feeding. This can easily be seen by letting a mosquito settle on the back of your hand and in peace allowed to take its satisfaction. In Tabanus, or the horse-fly, we have an intermediate modification of this type: the stylets are much reduced and shortened, well adapted for piercing, but no longer used for sucking, a function which has now become transferred to the labium, which forms a kind of fleshy tube known as the proboscis. An extreme modification of the type may be seen in the common housefly, where all the stylets have disappeared and only the proboscis remains as the sucking mouth organ. Diptera alone possess this type of mouth-parts.

5. **Rhynchota Type.** In this type the piercing and sucking mouth-parts are modified on a plan similar to that of the Diptera, but the two should not be confounded, as they are very distinct and show no phylogenetic relationship. The mandibles and the maxillæ form stylets similar to those of the Diptera; the labium is a strong, jointed tube or sheath in which the stylets are concealed. The labrum may be more or less produced but never forms a stylet, but rather serves as a covering or lid to the open furrow of the labium. No palps are present. Collectively the mouth-parts of the Rhynchota are known as a jointed beak or *rostrum*. This type is characteristic of the series Rhynchota or the orders Heteroptera and Homoptera.

The biramose type of appendages is found so often throughout the various classes of Arthropoda that it is now generally conceded to be the primitive type of arthropod appendage. What is meant by a biramose appendage will best be seen by examining one of the abdominal appendages of the cray-fish. This will be seen to be Y-shaped and made up of three parts or series of joints, viz: the basal part of two joints, attached to the body, is the *protopodite*; on the distal end of this there are two branches or rami composed of a varying number of joints: the branch attached to the inner side or next to the mid-axis of the body is the *endopodite;* the one on the outside of this is the *exopodite*. It is often stated that the insects are an exception to this and do not conform to the biramose type, but an examination of the mouth-parts makes it apparent that they are no exception to the rule. Comparing the maxilla of an insect with the arthropod type we may at once recognize in the cardo and the stipes the two joints of the protopodite; in the palp we have the outer rami or expodite and in the galea the endopodite. But in addition to this we have in the insects the lacinia as a third ramus to be accounted for, and it is no doubt this that has long obscured the homology. The lacinia of insects is homologous to the lacinia as seen in many Crustacea and other classes of the Arthropoda, where the protopodite has a jaw-function for grasping and crushing food, and in which the inner side of the protopodite is in consequence produced into a blade-like ridge known as the lacinia. In insects this ridge has become a separate joint and moved distally in its position on the stipes. That this is the case can be shown by examining the mouth-parts of many larvæ, and also in the adult form of Corydalis, where the lacinia still has its primitive position as a blade-like outgrowth from the side of the stipes and is not jointed.

LABORATORY DIRECTIONS TO CHAPTER V.

If there be time the student should dissect out the mouth-parts of the various types and mount them for examination under the microscope for drawing. Otherwise sets of the different types may be prepared by the instructor, in which case they may be used for successive classes. At all events it would be

well to have prepared sets for comparison, as the proper dissecting of the mouth-parts of insects presents many difficulties that can only be overcome by practice. A proper understand- of the mouth-parts is of very great importance for the classification of insects and should not be lightly passed over.

To prepare the mouth-parts for drawing, the head should be separated from the body and put into caustic potash for some hours or over night; after this the parts may be dissected out more easily and without separating them too much. The parts may now be transferred to absolute alcohol for dehydration, after which they should be treated for a few minutes in xylol or oil of cloves and mounted in the usual way in Canada balsam or xylol Damar. In case the mandibles are very thick and heavy in comparison with the other parts, they may be mounted separately or stuck on the same slide outside the cover glass by means of some balsam.

Plate VI. Fig. 13. x10.

Abdominal segment of the cray-fish with typical appendages.

Make a sketch and name the following parts: *D*, dorsal; *V*, ventral; *pro*, protopodite; *ex*, exopodite; *en*, endopodite.

Plate VI. Fig. 14. x10.

Mouth-parts of a Locust or the Cricket.

Make a sketch of the mouth-parts in their natural position and name the following parts: *M*, mandible; *Mx*, maxilla; *Lab*, labium; *Lbr*, labrum; *p*, palp; (exopodite); *g*, galea (endopodite); *l*, lacinia; *pr*, protopodite; *co*, cardo; *st*, stipes.

All the homologous parts of the labium should be named the same as for the maxilla.

Plate VII. Fig. 15. x10.

Mouth-parts of the Bee.

Sketch and name the following parts: *M*, mandible; *Mx*, maxilla; *Lab*, labium; *Lbr*, labrum; *pr*, protopodite; *co*, cardo; *st*, stipes; *p*, palpus (modified or reduced); *g*, galea (modified or wanting); *l*, lacinia (modified or tongue in the labium).

In this as in the preceding the same letters should be used for the parts of the labium as for the maxilla.

Plate VII. Fig. 16. x10.

Mouth-parts of the Butterfly.

Sketch and name the following parts: *Mx*, maxilla; *Lab*, labium; *pr*, protopodite; *p*, palp; *l*, lacinia (modified to form a spiral tongue in the maxilla, wanting in the labium).

Compare this with the mouth-parts of the cricket and see what parts are modified, and which have become reduced.

Plate VIII. Fig. 17. x10.

Mouth-parts of a Bug.

Sketch and name the following parts: *M*, mandible (stylet); *Mx*, maxilla (stylet); *Lab*, labium; number the joints of the labium beginning with the proximal joint; *Lbr*, labrum.

Note the absence of palps, and the fact that the larva has the same type of mouth-parts as the imago.

Plate VIII. Fig. 18. x10.

Mouth-parts of the Mosquito.

The simplest subtype of the Diptera mouth-parts is found in the mosquito or allied forms, but which, on account of their small size, are rather difficult to properly mount so that they can be examined under the microscope. It may be best to take half a dozen or more of the heads and treat them as directed above for the cricket, transfer all of them to the slide on which they are to be mounted in a drop of the clearing fluid, and with a pair of fine needles separate the stylets from the sheath formed by the labium before putting on the cover-glass; it is probable that one or more of the heads will show all the parts separated, from which the drawing can be made.

Sketch all the parts and name the following: *M*, mandible (stylet); *Mx*, maxilla (stylet); *Lbr*, labrum (stylet); *Ep*, epipharynx (stylet); *Lab*, labium; *Pl*, palp.

The mouth-parts of Tabanus (horse-fly) and Musca (house-fly) should also be examined and compared as subtypes of the above. These are more easily prepared as the specimens are much larger. If drawn, the same parts should be named as for the mosquito.

CHAPTER VI.

INTERNAL ANATOMY OF INSECTS.

The internal organs of insects may be considered under the following heads or systems.

1. **Muscular System.** The muscular system of insects is highly developed, as might be expected from the great activity shown, especially in the imago stage. The individual muscles are very great in number; in structure they are striated, similar to the voluntary muscles of higher animals. The different sets of muscles may be conveniently examined under the following divisions. (1) *Muscles of the body wall* segmentally arranged in sets or groups for each segment, and can best be examined in a freshly killed larva or in the abdomen of an adult insect. They are arranged in longitudinal, oblique, and dorso-ventral sets. (2) *Muscles of the appendages* which are the special sets of muscles of the antennæ, jaws, legs, and abdominal appendages. (3) *Muscles of the wings,* which are the largest and most important set of muscles of the imago. In color these are usually somewhat darker in a freshly killed insect than the other muscles. (4) *Muscles of the internal organs,* as those of the alimentary canal, the heart, etc.

2. **Alimentary System.** The alimentary tract of insects is a more or less straight tube extending from the anterior to the posterior end of the body. The tract presents great variation in length and in subdivision into parts, making it difficult to reduce to a common type. This might be expected as resulting from the great variety of food of insects: some feeding on animal while others on vegetable matter; some taking it in solid form while others as a liquid; some taking it fresh while others in a more or less decayed condition. From a study of the development of the tract we find that it may be divided in all cases into three primary divisions: the *fore-gut,* the *mid-gut,* and the *hind-gut.*

The fore-gut is an invagination of the mouth cavity at the anterior end of the body (*stomodaeum*); it is therefore lined by chitine similar to that of the body wall. It may be a simple tube, the *oesophagus*, extending from the mouth to the mid-gut; or it may contain several subdivisions besides the mouth, as the *pharynx*, *oesophagus*, *crop*, and *proventriculus*.

The mid-gut is not formed by an invagination from the outside, and therefore is not lined by chitine; but is formed independently in the embryo and is lined by endoderm epithelium, and later becomes connected with the fore-gut and the hind-gut into a single tube. The mid-gut forms the *stomach-intestine* of the tract.

The hind-gut is formed in the same way as the fore-gut, as an invagination from the posterior end of the body (proctodæum). This may also form a simple tube connecting the mid-gut with the anus, the *hind intestine*, or it may be subdivided into several parts usually called, but incorrectly so, the *ileum* or small intestine and the *colon* or large intestine with the rectum. The anus is always situated on the last segment.

The appendicula of the alimentary tract are: 1. *Salivary glands*, paired glandular organs opening into the mouth cavity and secreting a digestive fluid. Here belongs also the spinning-glands, silk-glands, etc., of many larvæ. 2. *Caeca* or diverticula of the mid-gut, usually present on the anterior part but very variable in form and numbers. They are accessory organs of digestion taking place in the mid-gut. 3. *Malpighian tubules*, long slender tubes lying free in the body cavity, but attached at the proximal end to the tract at the union of the hind-gut to the mid-gut. They are recognized as the principal excretory organs of insects. 4. *Rectal glands* and other accessory organs of the rectum.

3. **Respiratory System.** The respiration of insects is carried on by means of respiratory tubes or *tracheae* extending from the exterior, where they open as spiracles or stigmata, to all parts of the internal organs and supplying them directly with oxygen. In regard to this system it should be noticed: (1) that tracheæ originate as invaginations of the body wall and hence are lined with chitine on the inside secreted by the invaginated outside epithelium; (2) that these invaginations are seg-

mentally arranged, typically one pair to each segment, though the full number is rarely present; (3) that these paired tracheæ become united together in longitudinal tubes and by numerous cross-tubes into one system; (4) that in the chitinous lining of these tubes spiral bands or threads are developed which give elasticity to the tubes and which are of very great importance in the absence of any special muscles.

The respiratory system of insects shows a high degree of development, and should be contrasted with that of higher animals, as that of man; and also be compared with the circulatory system to show the correlation between the two.

4. **Circulatory System.** The circulatory system of insects consists of (1) the blood or body fluid, (2) a dorsal organ for the regulation of the flow of blood—the dorsal vessel or the heart.

The blood of insects consists of a colorless, or somewhat greenish or yellowish, fluid—the *serum*. In this is found a number of small cells or *corpuscles* which have amœboid movements.

The heart of insects consists of a longitudinal tube or vessel situated dorsally below the body wall. It is divided into a number of compartments corresponding in general with the segmentation of the body, each compartment supplied with a pair of lateral openings (*ostia*) by which the blood enters the heart. The vessel is suspended from the dorsal body wall in a chamber, the pericardial chamber, which is separated from the rest of the body cavity by a fenestrated membrane (*diaphragm*) stretched between the vessel and the alimentary tract.

The blood enters the dorsal vessel by the paired ostia and is propelled forward by a rhythmic contraction of the vessel; from this point it passes directly into the body cavity and flows, in more or less definite streams, in spaces (*lacunae*) between the various internal organs, bathing them in the fluid, and penetrating to all parts of the body. Gradually it is again returned to the pericardial chamber entering through the meshes of the diaphragm.

Some of the distinctive characters of the circulation of insects should be noticed: (1) it is principally a distribution of the digestive fluids as food for the various organs; (2) carrying of

refuse matter to be eliminated by the excretory organs; (3) the heart is a directive propelling-force; for the rest of the body the circulation is probably kept up in part by the muscular movements of the organs and by the amœboid movements of the corpuscles themselves; (4) the absence of red corpuscles for the carrying of oxygen, this being performed altogether by the respiratory system; (5) that the circulatory system is feebly developed in correlation with the respiratory and in comparison with the circulatory system of higher animals.

5. **Excretory System.** To the excretory system of insects belong: (1) *The malpighian tubules*, long slender tubes connected with the alimentary canal at the point of union of the hind-gut with the mid-gut; the typical number for insects seems to be from 2 to 6, this being the usual number in the larval period and for a large number in the imago. But in some of the Neuroptera in the Orthoptera and Hymenoptera the number becomes greatly increased in the imago, numbering from 20 to 150. (2) *The secretion of chitine* by the body wall, which is cast off from time to time in the process of moulting characteristic of all insects in the larval period.

6. **Nervous System.** The nervous system of insects consists of: (1) A central nerve-chord with the brain. (2) Sensory and motor nerves. (3) Accessory or sympathetic nerves.

The central nerve-chord consists of a series of ganglia segmentally arranged; each ganglion connected with the following by a double connective or two commissures. The anterior ganglion situated above the œsophagus constitutes the brain.

Sensory nerves are nerve fibers that connect the special sense organs, as the eyes, antennæ, palps, etc., with the central nervous system; transmitting sensations from the exterior to the brain. The motor nerves transmit sensations from the central nerve-chord to the various muscles.

The accessory or sympathetic system consists of nerves with gangliotic masses of nerve cells, that connects the internal organs as the alimentary tract, with the central nervous system.

7. **Reproductive System.** The sexes of insects are always separate, consisting of male and female. Externally there may be considerably difference between the two or they are quite

similar; but the internal organs of reproduction are very different in the two.

The primary parts of the female reproductive organs are: 1. *A pair of ovaries*, consisting of a varying number of egg-tubes connected at the proximal end to the next. 2. *A pair of oviducts* connecting the ovaries with the external opening of the system. 3. The two oviducts are usually united for some distance into a common duct, the *uterus*, reaching the exterior in a single opening. In addition to these there may be present as accessory parts (1) the *receptaculum semenis;* (2) *bursa copulatrix*, or copulatory pouch; (3) other accessory glands; and (4) external ovipositor.

The primary parts of the male reproductive organs are: 1. A pair of *testes*, consisting of a varying number of follicles. 2. A pair of *vasa defferentia*, or sperm ducts. 3. The posterior common portion of the two sperm ducts. In addition to these there may be present as accessory parts (1) seminal vesicles; (2) other accessory glands; (3) and external copulatory apparatus.

LABORATORY DIRECTIONS TO CHAPTER VI.

Plate IX. **Fig. 19.** **x3.**

Nervous system of the Caterpillar.

With a pair of fine pointed scissors, slit the larva open by carefully cutting through the body-wall along the mid-dorsal line, from the posterior to the anterior end; pin the specimen down under water in the dissecting-pan; with a pair of forceps carefully lift the sides of the cut body-wall and with the scalpel separate the internal soft parts so as to leave them in their natural position; pin the loosened flaps down. Now begin to separate the internal organs from each other and notice: (1) Fat tissue, covering more or less all the internal organs. (2) Tracheæ or respiratory tubes, their distribution and connection with the stigmata; examine some of the tracheæ under the microscope. (3) Alimentary tract. (4) Muscles of the body-wall. (5) Dissect out all the soft parts and expose the nerve chord on the ventral wall; make out the number and segmental arrangement of the

ganglia and the position of the brain. Make a sketch according to the scale and name the following parts: *gn,* ganglia; *cm,* commissures; number the ganglia of the thorax and the abdomen separately; *br,* brain; *ocm,* commissures around the œsophagus connecting the brain with the ventral chord; *nr,* nerves.

Plate IX. Fig. 20. x3.

Alimentary Tract of the Locust.

Sketch an outline of the body to the scale indicated from the left side. Cut off the legs and wings on the left side; with a pair of fine scissors make a slit through the body-wall along the dorsal and ventral margin of the left side; pin down under water; carefully dissect away the cut body-wall and the soft parts obscuring the alimentary tract. Sketch the tract in its natural position in the outline made above and name the following parts: *mo,* mouth; *oe,* œsophagus; *cr,* crop; *ce,* cæca; *st,* stomach-intestine; *hi,* hind-intestine; *ml,* malpighian tubes; *r,* rectum; *an,* anus.

Plate X. Fig. 21. x3.

Reproductive System of Locust.

In the same specimen just dissected or in a fresh one, make out the following parts of the reproductice system and sketch.

1. In the female: *o,* ovary; *ov,* oviduct; *cov,* common part of the two oviducts; *ovi,* ovipositor.

2. In the male: *t,* testes; *vd,* vasa differentia; *cvd,* common part of the two seminal ducts; *xr,* external reproductive organs.

Further directions may be given by the instructor, if so desired, on the internal anatomy; but the above may be sufficient to give a general idea of the internal anatomy of insects.

CHAPTER VII.

CLASSIFICATION OF INSECTS.

By classification of insects we aim not only to point out the differences there may be between the various kinds of insects, but also to show the similarity or degree of relationship. From a study of fossil insects we find that the various orders become more alike the further we go back in time, the differences that we now recognize as existing between the different orders gradually disappearing, until at last we have but one order retaining all of the more primitive characters. Paleontologists recognize such an order in the *Paleodictyoptera*, but it may also be deduced from a study of the structure and development of insects. This primitive order is characterized as having a campodiform larva, metamorphosis gradual and without a pupal stage, the two pairs of wings alike both in size and in characters, and the mouth-parts of the mandibulate type. But soon we notice that a modification is taking place in two directions, due no doubt to the different mode of life of some of these primitive insects. Some living close to the ground, concealing themselves among the grass, herbage, and rubbish, do not make much use of their wings except at the season of breeding and for the distribution of the species. In these the two pairs of wings tend to become dissimilar; remaining folded over the body, the front pair becomes thickened, serving as a protection; the second pair being the principal pair of use in flight, becomes folded in various ways to fit under the modified and reduced front pair. Others, living more exposed on bushes and trees, make more or less constant use of the wings as organs of locomotion, taking the place of the legs to a great extent in the imago stage. Here the two pairs of wings remain similar; the front wings being the principal pair of use in flight, the hind pair tending to become reduced in size. In the first the paleontologists recognize the *Orthopteroidea*, and in the second the *Neuropteroidea*. Almost simultane-

ous with the appearance of these two we have a third modification taking place, also due to the peculiar habit of the insect. Here the most important modification takes place not in the wings as in the first place but in the mouth-parts. These insects living a kind of parasitic or semiparasitic life upon plants, sucking their sap and juices, their mouth-parts become modified into a jointed beak or rostrum. This modification distinguishes the *Hemipteroidea* of the paleontologist. Now all the orders of the present time can be shown to be related to one or the other of these three orders of the earliest fossil forms with which we are acquainted; but at the present time we do not recognize them as orders, but as series, as each of them has split up into two or more orders. As a direct continuation of the Orthopteroidea we have the series *Plicata*, in which the two pairs of wings are dissimilar, the front pair modified for protection; the hind pair the principal pair of use in flight, and becoming folded in a peculiar way under the front pair when at rest. Coming directly from the Neuropteroidea we have the series *Aplicata*: the two pairs of wings remaining similar, the front pair the principal ones used in flight, the hind pair tending to become reduced in size or lost. From the Hemipteroidea we have the series *Rhynchota*, distinguished from all other insects by possessing a jointed beak. It should be remembered that this is a very primitive character and separates the Rhynchota from all other insects with sucking mouth-parts which can be shown to be of a much more recent origin. The wing characters here become of a secondary importance, but also show a modification in the two directions of the Plicata and the Aplicata. Belonging to the series Plicata we have the modern orders *Orthoptera* and *Coleoptera*. The Rhynchota split up into the orders *Heteroptera* and *Homoptera*. While to the Aplicata pertains the orders *Neuroptera*, *Hymenoptera*, *Lepidoptera*, and the *Diptera*. This relationship of the various orders of insects can be shown in a graphic way by the diagram, Figure 1.

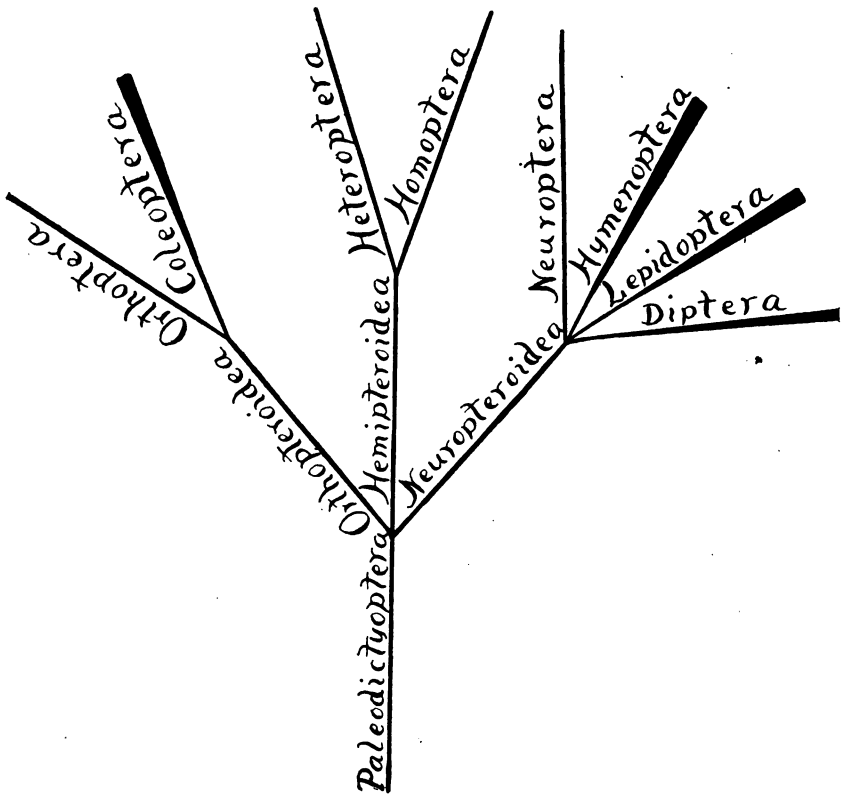
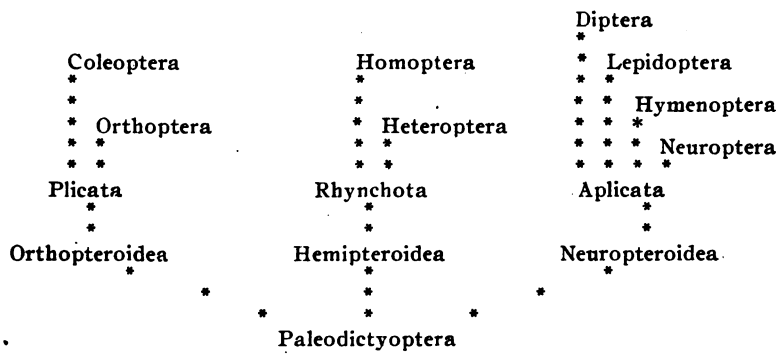


Fig. 1 Diagram of the Genealogy of Insects.

GENEALOGY OF INSECTS.



ORDERS OF THE CLASS INSECTA.

Class Insecta. Insects are distinguished from other classes of the great phylum Arthropoda by having the body divided into three regions: the head, thorax, and abdomen. The head carries one pair of antennæ and three pairs of mouth-parts. The three segments of the thorax are each provided with a pair of legs; and the last two usually with a pair of wings to each in the adult stage. The abdomen has no legs, but may have some greatly modified terminal appendages, as cerci, etc. Respiration is by means of tracheal tubes that penetrate to all parts of the body, opening to the exterior in paired stigmata segmentally arranged.

A. Series I.—**Plicata.** Mouth-parts of the mandibulate type both in the larva and the imago stage. The two pairs of wings dissimilar in character: the front pair modified for protection, often of little or no use in flight; hind wings membranous and folded in various ways under the front pair when at rest. Prothorax free and usually well developed. Terrestrial insects, living mostly close to the ground and making use of the legs for ordinary locomotion in the imago as well as in the larva; the wings being used as the principal organs of locomotion in connection with reproduction and the distribution of the species.

Order 1.—**Orthoptera.** The front pair of wings is parchment-like (tegmina), much reduced in size in comparison with the hind pair. The hind pair of wings membranous and folded

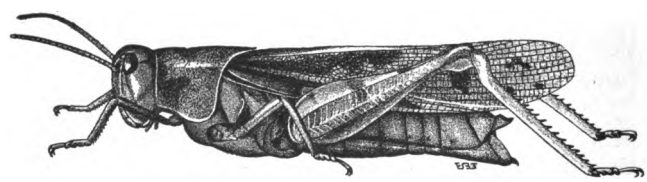


Fig. 2. Orthoptera. Locust.

longitudinally or fan-like when at rest. Abdomen usually provided with cerci. Metamorphosis gradual and the larva campodiform, similar to the imago except in size and in the absence of wings.

Some of the Orthoptera become musical in the imago and in consequence have well developed organs of hearing, which may be found on various parts of the body, as the abdomen, the legs, etc. We have about 100 different kinds of Orthoptera in Minnesota; and they are commonly known as Cock-roaches, Walking-Sticks, Locusts, Grasshoppers, and Crickets.

Order 2.—**Coleoptera.** The front pair of wings is short and shield-like (elytra), fitting closely over the hind part of the body; in some cases much shorter than the abdomen. The hind wings are large and membranous, when at rest folded transversely and longitudinally so as to fit under the elytra; abdomen without cerci. Metamorphosis interrupted, and the larva may be campodiform, eruciform, or even apodiform; but in all cases passing through a distinct pupa stage before reaching the imago.

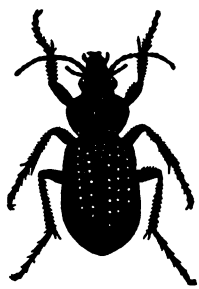


Fig. 3. Coleoptera. Bettle.

The beetles are very numerous in species; of some 12,000 known to occur in North America, probably one-fourth will be found in Minnesota. A great number are predacious, feeding upon other insects, and can be found running about on the ground, or hiding under bark, stones, or rubbish. A number can be found on flowers and plants feeding upon leaves and other parts. Those feeding upon dung, dead animal and vegetable matter, must be looked for in such places. A few are aquatic, some of which are attracted by electric lights. The beetles, though forming the largest and probably the best defined order, nevertheless show very great variation in form and in habit.

B. Series II.—**Rhynchota.** The mouth-parts form a jointed beak or rostrum adapted for piercing and sucking. The sucking mouth-parts are already present as such at the time of hatching of the larva and remain the same in the imago as in the larva. The wings are variously modified; apterous or wingless condition not uncommon. Cerci wanting. Living mostly on plants, piercing the tissue and sucking the juices; some are predacious, sucking the blood of animals.

Order 3.—**Heteroptera.** Rostrum arising from the front of the head. The two pairs of wings dissimilar: the front pair with the base thickened, while the apex remains membranous; the hind pair all membranous, and usually smaller in size. Metamorphosis gradual.

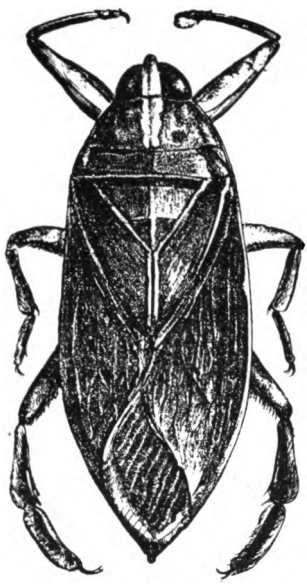


Fig. 4. Heteroptera. Electric-Light Bug.

To this order belong the true bugs, as the Chinch-bug, Squash-bug, Bed-bug, etc. They are commonly to be found on the various plants, on which they feed, or under bark, among the grass, and some also are attracted by electric lights.

Order 4.—**Homoptera.** Rostrum arising from the ventral side of the head, the two pairs of wings similar, and usually held roof-like over the body when at rest. Front pair sometimes thicker, and the hind-pair often smaller. Metamorphosis gradual, but interrupted in a few cases as in the males of the Coccidæ.

To this order belong the Cicadas, Tree-hoppers, Plant-lice, etc. The majority of homoptera are small insects, and are to be looked for on various plants and among grass.

C. Series III. — **Aplicata.** Mouth-parts mandibulate throughout life or becoming modified for sucking in the imago, in which case they are of a very different type from that of the larva. The two pairs of wings are membranous and similar in character. The front pair usually the larger and the principal pair for use in flight the hind pair often much smaller or even lost. Prothorax usually narrow and fused to the mesothorax. Aerial insects living more exposed in the adult stage and whose locomotion is usually by means of wings, the legs becoming of secondary importance.

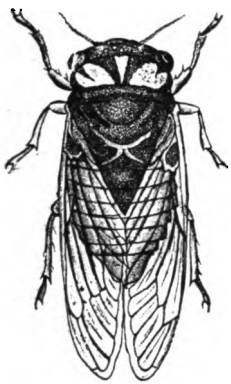


Fig. 5. Homoptera. Cicada.

Order 5.—**Neuroptera.** Mouth-parts mandibulate in the imago as well as in the larva. The membranous wings, large in comparison with the body, and provided with numerous veins and cross-veins forming a complex reticulation. Metamorphosis gradual or interrupted.

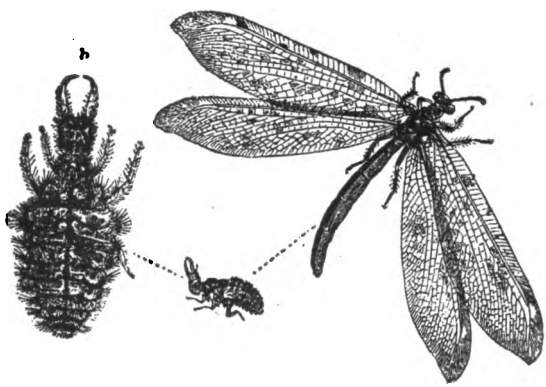


Fig. 6. Neuroptera. Ant-lion.

The order Neuroptera contains insects that vary so much among themselves that they are now usually considered as forming separate orders, but for practical purposes it may be taken, as here, in its widest sense; as the order, even then, is not numerous in species in comparison with the following. The group is phylogenetically fairly natural in the mouth characters and somewhat less so in the wing characters. Some of the best known forms are probably the may-flies, dragon-flies, etc. Many of them are aquatic in the larva stage, and most of them are found in somewhat damp situations along streams and borders of lakes.

Order 6.—**Hymenoptera.** Mouth-parts partake both of the biting and the sucking type. In some larvæ they are typically mandibulate, while in others they become more or less modified as a result of their parasitic habit or the social instinct of the adult. In the imago the mandibles are always present; the maxillæ may be more or less modified as accessory organs of the labium, which forms the tongue-like organ in this order adapted for feeding on pollen and fluids. The wings are thin and membranous, the hind pair usually much smaller; veins never very numerous. The attachment of the abdomen to the thorax is usually narrow. Metamorphosis trophic.

Here belong the Saw-flies, Wasps, Ants, Bees, and other

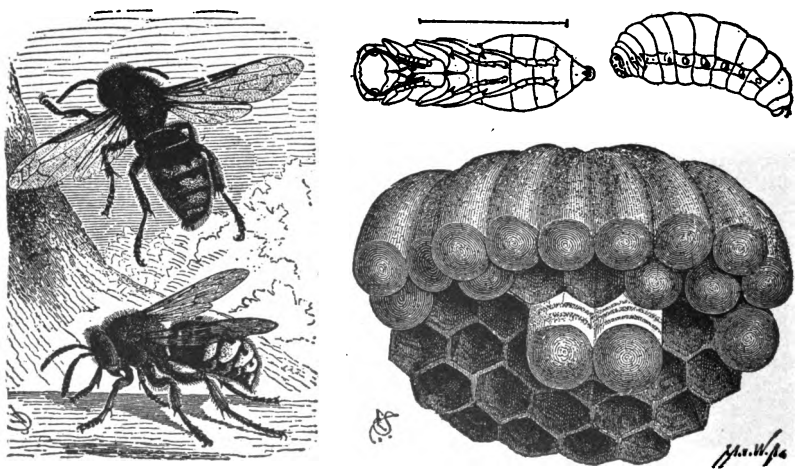


Fig. 7 Hymenoptera. Wasps.

Hymenoptera and they are to be found in abundance on plants, especially on flowers, feeding on the pollen of the same.

Order 7.—**Lepidoptera.** Mouth-parts of the larva are mandibulate, but in the imago they are suctorial. The mandibles are lost; the maxillæ form the long spiral tongue; the labium is much reduced except the palps. Prothorax narrow and fused with mesothorax. Wings and body clothed more or less with hairs and scales. Abdomen broadly attached to the thorax. Larvæ feeding on vegetable matter and known as caterpillars. Metamorphosis trophic.

Fig. 8. Lepidoptera. Butterfly.

The conspicuous butterfly can easily be taken feeding on flowers; the moths, which are night fliers, can usually be found in the day-time hiding under loose bark, in outhouses, and in other secluded places; a number are attracted by electric lights.

Order 8.—**Diptera.** The primitive mouth-parts of the larvæ of the Diptera are mandibulate, but have become more or less modified, due to the peculiar conditions under which the larvæ develop. In the imago they become changed into piercing and sucking mouth-parts, following a type peculiar to this order. When the piercing organs are present they are formed of the mandibles, maxillæ, the labrum, and the epipharynx; in the higher forms in which the piercing organs have become lost, the labium alone forms the sucking tube or a fleshy proboscis. Prothorax narrow and fused. Only one pair of wings is present, the hind wings replaced by a pair of knob-shaped bodies called the halteres or balancers. Larvæ usually apodiform and known as maggots. Metamorphosis trophic.

Here belongs the true or two-winged flies as the mosquito, the common house fly, etc. The order is very numerous in species, probably some two thousand are to be found in Minnesota alone. They can be looked for on windows in houses, and are usually numerous in places of rich vegetation and on flowers.

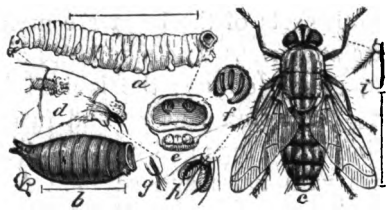


Fig. 9. Diptera. Fly.

KEY TO THE ORDERS.

A. *Series I. Plicata.* Mouth-parts mandibulate; the two pairs of wings dissimilar; hind pair folded under front pair when at rest.

a. Front wings forming tegmina; hind wings folding fan-like.

Order 1. *Orthoptera.*

aa. Front wings forming elytra; hind wings folded transversely.

Order 2. *Coleoptera.*

B. *Series II. Rhynchota.* Mouth-parts forming a jointed beak; wings variously modified.

b. Front wings forming hemelytra, thick at base, membranous at tip; hind wings all membranous.

Order 3. *Heteroptera.*

bb. The two pairs of wings membranous and similar, or nearly so, not forming hemelytra.

Order 4. *Homoptera.*

C. *Series III. Aplicata.* Mouth-parts mandibulate or adapted for sucking; the two pairs of wings membranous and similar, the hind pair usually smaller.

c. Mouth-parts mandibulate in imago as weli as in larva; wings membranous with numerous veins and cross-veins.

Order 5. *Neuroptera.*

cc. Mandibles present but the labium forming a tongue in the imago; wings membranous and with few veins.

Order 6. *Hymenoptera.*

ccc. Mouth-parts a spiral proboscis or tongue formed of the maxillæ; body and wings covered with colored scales or hairs.

Order 7. *Lepidoptera.*

cccc. Mouth-parts a fleshy proboscis formed of the labium; only one pair of wings present, membranous.

Order 8. *Diptera.*

CHAPTER VIII.

DIRECTIONS FOR MAKING A COLLECTION OF INSECTS.

The student is required to make a collection of at least fifty species of insects, representing the different orders given in the preceding chapter. The apparatus necessary to make such a collection need not be many nor expensive. The following should at once be secured by the student.

1. A couple of empty cigar boxes for holding the insects.

2. A paper of insect pins and a sheet of cork for lining the boxes. The cork may be cut into narrow strips and tacked or glued into the bottom of the boxes.

3. A killing bottle. This should be a wide-mouthed bottle holding about four ounces and of convenient shape to be carried in the pocket. In case chloroform, ether, or benzine is used for killing, nothing more is necessary. But a permanent killing bottle can easily be prepared by taking a piece of cyanide of potassium (a deadly poison) about the size of a small nut, drop it into the wide-mouthed bottle and pour on water enough to cover the cyanide, then put in plaster of Paris sufficient to absorb all the water. Put the bottle away in an open place uncorked, until the plaster has well set. When corked the fumes from the cyanide will be sufficient to kill all insects put in, and it will last for the season.

4. A net. Though a small collection as here required can be made without having a net, the use of one will greatly facilitate the work. It can be purchased, or the student can also make his own at practically no cost. Secure a strong wire, bend this into a circle about one foot in diameter, and fasten this to a convenient handle about three feet in length. Make a bag of cheese-cloth or some other light material about 18 inches

deep somewhat rounded at the closed end, and sew this on to the frame and your net is ready.

After securing and killing your insect give it a careful examination, make out its essential characters, and determine the order to which it belongs according to the scheme given in the preceding chapter. This work should be done on the same day the specimen is killed or at least on the following, or else it will become so dry and brittle that a close examination of the mouth-parts and wings will cause them to break off. In case your specimens have become too dry before you are able to examine, they may again be relaxed by putting them on a wet cloth under an inverted tumbler or jar for a few hours or over night, when they again will become soft and may be safely handled and examined. After a satisfactory examination of the specimen it should be pinned. Insects are all pinned through the thorax with the exception of the Coleoptera, which are always pinned through the right wing cover. The specimen should be raised high enough on the pin so that one fourth of the pin remains above. Care should also be taken that all the specimens are pinned at the same height. A small label with the date and place of capture should now be prepared and put on the pin below the specimen. Now the specimen is ready to be put in the box under the heading of the order to which it belongs.

Where to look for specimens of the various orders is briefly referred to in the preceding chapter.

If further directions are desired in regard to collecting and preserving insects, these can be found in Riley's "Directions for Collecting and Preserving Insects"; in Packard's "Entomology for Beginners"; and in Comstock's most delightful little book, "Insect Life."